

US EPA ARCHIVE DOCUMENT

**DATA COLLECTION FOR THE  
HAZARDOUS WASTE IDENTIFICATION RULE**

**SECTION 10.0 FARM FOOD CHAIN AND  
TERRESTRIAL FOODWEB DATA**

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## DISCLAIMER

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## 10.0 Farm Food Chain and Terrestrial Food Web Data

This section presents the data compilation strategies and methods implemented to develop the databases in support of the farm food chain (FFC) and the terrestrial food web (TFW) modules. Data were collected to quantify parameters required to develop exposure profiles for receptors in these respective food webs. These parameters include bioaccumulation factors, partitioning coefficients, and ingestion rates that the modules use to estimate movement of constituents through food webs. The FFC module is used to assess exposure to humans that may occur through consumption of beef, milk, and agricultural products, while the TFW is used to assess exposure to wildlife through ingestion of typical terrestrial prey items.

Because many of the parameters required for the FFC also were applied to the TFW, the databases that were developed contain the necessary parameters for both food webs. The selected receptors and their respective prey preferences constitute the primary differences between the FFC and the TFW; however, many of the exposure relationships are similar. Two general databases were generated for these food webs: a chemical-specific database and an exposure-related database. The chemical-specific parameters vary depending on the constituent evaluated, whereas the exposure-related database consists of parameters that represent uptake and deposition rates, empirical correction factors, and adjustment fractions to account for reductions in potential exposures. Sections within this report were constructed using the two database categories (i.e., chemical-specific and exposure-related). In reviewing the methods used to develop the chemical-specific database and the key uncertainties (Sections 10.3 and 10.4), however, discussions are further categorized by food webs (e.g., FFC and TFW). For this documentation, the overlapping parameters between the FFC and the TFW are reviewed within the FFC discussions, while the parameters specific to the TFW are the only parameters reviewed in discussions of the TFW.

### 10.1 Parameters Collected

This section presents the parameters included in each database. Parameters included in the chemical-specific database are presented in Table 10-1, and exposure-related parameters are presented in Table 10-2. A brief description of each parameter is provided for clarity.

#### 10.1.1 Chemical-Specific Database

The chemical-specific parameters used in the FFC and the TFW are provided in Table 10-1. The TFW uses the same chemical-specific parameters as the FFC, with the exception of biotransfer and bioavailability factors that are used to quantify uptake in FFC

**Table 10-1. Farm Food Chain and Terrestrial Food Web Chemical-Specific Parameters**

Parameter	Unit	Description	Module
ChemBa_{ <i>item</i> }	d/g	These biotransfer factors quantify the fraction of constituents transferred from food stocks (e.g., vegetation) and water into beef and milk products	FFC
ChemBs	fraction	Fraction of contaminant concentrations in soil that is bioavailable to vegetation	FFC
ChemBr_{ <i>plant category</i> }	[ $\mu\text{g/g}$ DW plant]/ [ $\mu\text{g/g}$ soil]	Fraction of constituents in soil taken up into plant tissues. Assessed for the following plant categories: exposed fruits, exposed vegetables, forage, grain, protected fruits, protected vegetables, roots, silage	FFC and TFW
ChemBv_ecf_plant	unitless	Empirical correction factor for air-to-plant biotransfer factor	FFC and TFW
ChemBv_{ <i>plant category</i> }	[ $\mu\text{g/g}$ DW plant]/ [ $\mu\text{g/g}$ air]	Fraction of constituents in air taken up into plant tissues. Assessed for the following plant categories: exposed fruits, exposed vegetables, forage, silage	FFC and TFW
ChemHLC	(atm m <sup>3</sup> )/mol	Henry's law constant	FFC and TFW
ChemKd	L/kg	Soil/pore water partition coefficient	FFC and TFW
ChemKoc	mL/g	Organic carbon partition coefficient	FFC and TFW
ChemKow	N/A	Octanol-water partition coefficient	FFC and TFW
ChemkpPar_{ <i>plant category</i> }	1/yr	Loss coefficient of particle-bound contaminants on plant surfaces. Assessed for the following plant categories: exposed fruits, exposed vegetables, forage, silage	FFC and TFW
ChemkpVap_{ <i>plant category</i> }	1/yr	Loss coefficient of vapor-phase constituents on plant surfaces. Assessed for the following plant categories: exposed fruits, exposed vegetables, forage, silage	FFC and TFW
ChemRCF	[ $\mu\text{g/g}$ WW plant]/ [ $\mu\text{g/mL}$ sl water]	Fraction of constituents in soil pore water taken up into root tissue	FFC and TFW
ChemBAF_{ <i>prey type</i> }	unitless	Bioaccumulation factors for small birds, herbivorous vertebrates, small herpetofauna, invertebrates, small mammals, omnivorous vertebrates, and earthworms	TFW

**Table 10-2. Farm Food Chain and Terrestrial Food Web Exposure-Related Parameters**

Parameter	Unit	Description	Module
$F_{\{item\}_{cattle\ type}}$	fraction	Fraction of food stock (e.g., forage, grain, silage) grown in contaminated soil. Identified for beef and dairy cattle	FFC
$Qp_{\{item\}_{cattle\ type}}$	kg DW/d	Consumption rate of food stock (e.g., forage, grain, silage) by cattle. Assessed for beef and dairy cattle	FFC
$Qs_{cattle\ type}$	kg/d	Consumption rate of soil by cattle. Assessed for beef and dairy cattle	FFC
$Qw_{cattle\ type}$	L/d	Consumption rate of water by cattle. Assessed for beef and dairy cattle	FFC
$Fw_{plant\ category}$	unitless	Fraction of wet deposition that adheres to plant surfaces. Assessed for the following plant categories: exposed fruits, exposed vegetables, forage, silage	FFC and TFW
$MAF_{plant\ category}$	percentage	Moisture adjustment factor used to convert plant tissue data from dry weight to wet weight. Assessed for the following plant categories: exposed fruits, exposed vegetables, wet leaf, protected fruits, protected vegetables, roots	FFC and TFW
$\rho_{leaf}$	g/L FW	Leaf density	FFC and TFW
$Rp_{plant\ category}$	unitless	The fraction of deposition that intercepts plant surfaces. Assessed for the following plant categories: exposed fruits, exposed vegetables, forage, silage	FFC and TFW
$tp_{plant\ category}$	yr	Duration of plant exposure to deposition on an annual basis. Assessed for the following plant categories: exposed fruits, exposed vegetables, forage, silage	FFC and TFW
VapDdv	cm/s	Vapor-phase dry deposition velocity	FFC and TFW
$VGag_{plant\ category}$	unitless	Empirical correction factor that accounts for volumetric differences among aboveground vegetation parts. Assessed for the following plant categories: exposed fruits, exposed vegetables, forage, silage, root.	FFC and TFW
VGbg_root	unitless	Empirical correction factor that accounts for volumetric differences among roots of different plant categories	FFC and TFW
$Yp_{plant\ category}$	kg DW/m <sup>2</sup>	Crop yield for plant categories: exposed fruit, exposed vegetables, forage, silage	FFC and TFW



receptors (i.e., ChemBa and ChemBs). In the TFW, these parameters were not applied; rather, parameters were included to characterize the uptake of constituents into various terrestrial prey items (e.g., ChemBAF{prey type}).

### 10.1.2 Exposure-Related Database

The exposure-related parameters in the FFC and the TFW are provided in Table 10-2. The exposure-related parameters for the TFW are the same as the FFC parameters, except that the parameters specific to cattle type, which are relevant only to human exposure, are not included in the TFW (i.e., F{item}\_{cattle type}, Qp\_{item}\_{cattle type}, Qs\_{cattle type}, and Qw\_{cattle type}).

## 10.2 Data Sources

This section presents the primary data sources identified to develop the databases and information by food web type rather than by database type. In general, data were compiled for the FFC and TFW database from data reviews, as well as the primary literature.

### 10.2.1 Farm Food Chain

The majority of the information for the FFC database was taken from two U.S. Environmental Protection Agency (EPA) documents:

- (1) *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions* (U.S. EPA, in press) and
- (2) *Parameter Guidance Document* (U.S. EPA, 1997a).

Although both were draft documents currently under review, they were the preferred data sources because they were developed in accordance with EPA's policies and standards. All available data from these two sources were compiled, and then the remaining data gaps were filled using values derived in previous Hazardous Waste Identification Rule (HWIR) database development (Research Triangle Institute [RTI], 1995) and other more current primary references. The data sources consulted to assemble the databases are presented in Tables 10-3 and 10-4 for chemical-specific and exposure-related parameters, respectively.

### 10.2.2 Terrestrial Food Web

Terrestrial food web parameters not included in the FFC discussion consisted of chemical uptake factors for terrestrial prey items. The search strategy implemented for identifying terrestrial uptake factors consisted of two basic steps: surveying current compendia and databases and conducting a focused online literature search to identify key resources specific to constituents and prey items.

**Table 10-3. Data Sources for Farm Food Chain Chemical-Specific Parameters****ChemBa\_{item}*****Dioxin and Organics***

U.S. EPA (Environmental Protection Agency). In press. *Methodology for Assessing Health Risks Associated With Multiple Exposure Pathways to Combustor Emissions*. EPA, National Center for Environmental Assessment, NCEA-0238.

***Mercury and Metals***

Baes, C.F., III, R.D. Sharp, A.L. Sjoreen, and R.W. Shor. 1984. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture*. Oak Ridge National Laboratory, ORNL--5786. Oak Ridge, TN.

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**ChemBs**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**ChemBr\_{plant category}*****Organics and Mercury***

U.S. EPA (Environmental Protection Agency). In press. *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions*. EPA, National Center for Environmental Assessment, NCEA-0238.

***Metals***

California Department of Food and Agriculture (CDFA). 1998. *Development of Risk-Based Concentrations for Arsenic, Cadmium, and Lead in Inorganic Commercial Fertilizers*. Prepared by Foster and Wheeler Environmental Corporation, Sacramento, CA.

Sample, B.E., M.S. Aplin, R.A. Efroymsen, G.W. Suter II, and C.J.E. Welsh. 1997. *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants*. Oak Ridge National Laboratory, Oak Ridge, TN.

U.S. DOE (Department of Energy). 1998a. *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants*. BJC/OR-133. Prepared for U.S. Department of Energy, Oak Ridge National Laboratory, Oak Ridge, TN.

Chaney, R.L., and J.A. Ryan. 1994. *Risk Based Standards for Arsenic, Lead, and Cadmium in Urban Soils*. DECHEMA Deutsche Gesellschaft fur Chemisches Apparatewesen, Chemische Technik und Biotechnologie e. V., Frankfurt am Main.

**ChemBv\_ecf\_plant**

U.S. EPA (Environmental Protection Agency). In press. *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions*. EPA, National Center for Environmental Assessment, NCEA-0238.

*(continued)*

**Table 10-3. (continued)**

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**ChemBv\_{plant category}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

Simonich, S.L., and R.A. Hites, 1994. Vegetation-atmosphere partitioning of polycyclic aromatic hydrocarbons. *Environmental Science and Technology* 28:939-943.

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**ChemkpPar\_{plant category}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

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**ChemkpVap\_{plant category}**

U.S. EPA (Environmental Protection Agency). In press. *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions*. EPA, National Center for Environmental Assessment, NCEA-0238.

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**ChemRCF**

RTI (Research Triangle Institute). 1995. *Technical Support Document for the Hazardous Waste Identification Rule: Risk Assessment for Human and Ecological Receptors, Volumes 1 and 2, 1995*. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste. Prepared by Research Triangle Institute.

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

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**Table 10-4. Data Sources for Farm Food Chain Exposure-Related Parameters****F{item}\_{cattle type}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**Fw\_{plant category}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**MAF{plant category}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**Qp\_{item}\_{cattle type}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**Qs\_{cattle type}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**Qw\_{cattle type}**

Harris B., Jr., and H.H. Van Horn. 1992. *Water and Its Importance to Animals*. Circular 1017, Dairy Production Guide, Florida Cooperative Extension Service. Available online at <http://hammock.ifas.ufl.edu/txt/fairs/2607>.

University of Nebraska Cooperative Extension. 1998a. *Water Requirements for Beef Cattle*. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Available online at <http://www.ianr.unl.edu/pubs/beef/g372.htm>.

University of Nebraska Cooperative Extension. 1998b. *Water Quality and Requirements for Dairy Cattle*. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln. Available online at <http://www.ianr.unl.edu/pubs/dairy/g1138.htm>.

USDA (U.S. Department of Agriculture). 1998. *Statistical Highlights 1997-98: Livestock*. USDA National Agricultural Statistics Service. Available online at <http://www.usda.gov/nass/pubs/stathigh/1998/lv-ca-sl.htm>.

**rho\_leaf**

U.S. EPA (Environmental Protection Agency). In press. *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions*. EPA, National Center for Environmental Assessment, NCEA-0238.

**Rp\_{plant category}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**tp\_{plant category}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**VapDdv**

U.S. EPA (Environmental Protection Agency). In press. *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions*. EPA, National Center for Environmental Assessment, NCEA-0238.

**VGag\_{plant category}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**VGbg\_root**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

**Yp\_{plant category}**

U.S. EPA (Environmental Protection Agency). 1997a. *Parameter Guidance Document*. EPA, National Center for Environmental Assessment, NCEA-0238.

- # Survey of current compendia and databases: This step consisted of identifying databases compiled by other government agencies outside EPA (e.g., the National Oceanic and Atmospheric Administration [NOAA]) and private laboratories and ongoing database development at RTI in support of other Office of Solid Waste (OSW) projects. The survey of compendia helped to identify key review papers and current work being conducted on particular receptors and constituents. In addition, EPA and other government Web sites were searched to identify new or updated databases that could be easily accessed.
- # Focused online literature searches: The survey results identified papers on uptake factors that were used to inform and focus the online literature search. Online searching primarily used the Toxline/Medline reference databases.

The key sources identified to collect uptake data for the TFW are presented in Table 10-5. To quantify uptake into terrestrial plants, the FFC parameters for ChemBr forage parameters were adopted.

**Table 10-5. Data Sources for Terrestrial Food Web Chemical-Specific Parameters**

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**Vertebrates<sup>1</sup>**

Garten, C.T., Jr., and J.R. Trabalka. 1983. Evaluation of models for predicting terrestrial food chain behavior of xenobiotics. *Environmental Science and Technology* 590-595.

Rowe, C.L., O.M. Kinney, A.P. Fiori, and J.D. Congdon. 1996. Oral deformities in tadpoles (*Rana catesbeiana*) associated with coal ash deposition: Effects on grazing ability and growth. *Freshwater Biology* 36:723-730.

Sample, B.E., J.J. Beauchamp, R.A. Efroymsen, and G.W. Suter, II. 1998. *Development and Validation of Bioaccumulation Models for Small Mammals*. ES/ER/TM-219. Oak Ridge National Laboratory, Oak Ridge, TN.

RTI (Research Triangle Institute). 1995. *Technical Support Document for the Hazardous Waste Identification Rule: Risk Assessment for Human and Ecological Receptors - Volumes I and II*. Prepared for the Office of Solid Waste, U.S. Environmental Protection Agency under Subcontract No. 801-01.

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**Earthworms**

Sample, B.E., J.J. Beauchamp, R.A. Efroymsen, and G.W. Suter, II. 1998. *Development and Validation of Bioaccumulation Models for Small Mammals*. ES/ER/TM-219. Oak Ridge National Laboratory, Oak Ridge, TN.

U.S. EPA (Environmental Protection Agency). 1997b. *Risk Assessment for the Waste Technologies Industries (WTI) Hazardous Waste Incineration Facility. Volume VI: Screening Ecological Risk Assessment*. EPA-905-R-97-002f. Region 5 Waste, Pesticides and Toxics Division. Chicago, IL.

Van Gestel, C.A.M. and W. Ma. 1988. Toxicity and bioaccumulation of chlorophenols in earthworms, in relation to bioavailability in soil. *Ecotoxicology and Environmental Safety* 15:289-297.

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**Invertebrates**

U.S. DOE (Department of Energy). 1998b. *Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation*. BJC/OR-112. Oak Ridge, TN.

Wu, L., J. Chen, K.K. Tanji, and G.S. Banuelos. 1995. Distribution and biomagnification of selenium in a restored upland grassland contaminated by selenium from agricultural drain water. *Environmental Toxicology and Chemistry* 14(4):733-742.

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<sup>1</sup> Vertebrates include small mammals, small birds, small herpetofauna, omnivorous vertebrates, and herbivorous vertebrates.

## 10.3 Methodology

The review of methods implemented for developing these databases was first organized around the two types of data generated (i.e., chemical-specific and exposure-related); within these descriptors, methods are presented for the FFC and the TFW. Because parameters unique to the TFW comprise chemical-specific parameters only, a discussion of the terrestrial food web was not necessary under the exposure-related database. Methods are presented on a parameter-specific basis. The final values adopted into the databases are presented in Appendix 10A for the chemical-specific database and Appendix 10B for the exposure-related database. Note that some chemical-specific parameters included in the database are not included in the methods discussion. These parameters include ChemHLC, ChemKow, ChemKd, and ChemKoc. Values for these parameters were supplied by EPA's Office of Research and Development (ORD), Athens, Georgia.

### 10.3.1 Chemical-Specific Database

This section presents the methods used to identify chemical-specific data for the FFC and TFW modules. Parameters related to each food web are discussed separately. The FFC parameters are reviewed in Section 10.3.1.1 and the TFW parameters are reviewed in Section 10.3.1.2.

#### 10.3.1.1 Database Compilation and Processing for Farm Food Chain

**10.3.1.1.1 Biotransfer Factors.** Biotransfer factors, ChemBa\_beef and ChemBa\_milk, are specific to cattle type (e.g., beef and dairy). The FFC module uses biotransfer factors to calculate the total contaminant concentration in beef and milk resulting from consumption of contaminated vegetation. Contaminant concentrations in plant tissue are included on a fresh weight basis. Typically, experimentally derived biotransfer factors are preferred, but in cases where sufficient data are unavailable, biotransfer factors are estimated based on  $\log K_{ow}$ .

For organic compounds, the following approach was implemented to develop biotransfer factors. The octanol-water partition coefficient,  $K_{ow}$ , can be used to estimate biotransfer factors for beef and milk in the absence of experimental data. Travis and Arms (1988, as cited in U.S. EPA, in press) derived empirical relationships between  $K_{ow}$  and biotransfer factors for beef and milk to produce estimates of ChemBa that predict whole-beef and whole-milk concentrations on a freshweight basis given dietary uptake of organic contaminants in terms of mass ingested/d. Equations 10-1 and 10-2 were used to estimate the biotransfer of constituents into milk and beef.

$$\text{Log ChemBa}_{\text{milk}} = -8.1 + \log K_{ow} \quad (10-1)$$

$$\text{Log ChemBa}_{\text{beef}} = -7.6 + \log K_{ow} \quad (10-2)$$

where

ChemBa_milk	=	biotransfer factors from plant to milk.
ChemBa_beef	=	biotransfer factors from plant to beef.
K <sub>ow</sub>	=	octanol-water partition coefficient.

These correlations were derived from experimental uptake data for milk and beef. Correlations derived for milk were based on 28 organic constituents with K<sub>ow</sub> values ranging from 2.8 to 6.5. For beef, correlations were based on 36 organic constituents with log K<sub>ow</sub> values ranging from 1.3 to 6.9. The equations given in U.S. EPA (in press) were applied to organics and special constituents with log K<sub>ow</sub> values within the respective ranges. Constituents with K<sub>ow</sub> values outside the range were assigned the default value of 1 d/g animal tissue.

The equations used for organics were inappropriate for dioxins because the correlations tend to overestimate the transfer of dioxins to milk and beef. For dioxins, the milk biotransfer factor of 1E-05 d/g animal tissue was taken from U.S. EPA (in press). This value was based on measured biotransfer factors and was considered more representative than predicted values. The milk biotransfer factor was converted to a beef biotransfer factor based on the assumed fat content in beef and milk. Dioxins tend to bioconcentrate equally in the fat of beef and milk. For this reason, the excretion of dioxins in milk is expected to be matched by the dilution of the contaminant in beef tissue. Assuming that milk is 3.5 percent fat and beef is 19 percent fat, the biotransfer factor for beef would be 5.4, times higher (i.e., 19/3.5) than for milk. Therefore, the Ba<sub>beef</sub> was calculated by multiplying Ba<sub>milk</sub> by 5.4, resulting in a biotransfer factor of 5.4E-05 d/g animal tissue. This value was adopted as the beef biotransfer factor for dioxins.

Beef and milk biotransfer factors for metals were adopted from Baes et al. (1984). Baes et al. (1984) developed regression equations to predict the transfer of metals into beef and milk in cattle. The total mercury biotransfer factors recommended in U.S. EPA (1997a) were adopted for this analysis. For other metals, where data were insufficient to develop a biotransfer factor, the default value of 2E-05 d/g of tissue was used.

**10.3.1.1.2 Bioavailability Fraction.** The bioavailability fractions, ChemBs and ChemBa\_water, account for the bioavailability of a contaminant in the soil relative to its bioavailability in vegetation and the bioavailability of a contaminant in drinking water ingested by beef and dairy cattle, respectively. These parameters account for the fraction of the total chemical concentration in soil and drinking water that may be in a chemical form that is not bioavailable. In the absence of data regarding constituent bioavailability in these respective media, this factor was assigned a default value of 1, as recommended by U.S. EPA (1997a).

For dioxins, a mean value derived from a reported range was adopted for this parameter. The fraction of dioxin that remains bioavailable as it moves from soil to plant ranged from 0.5 to 0.8; the mean of 0.65 was adopted for this analysis (U.S. EPA, 1997a). This data range was derived from studies reporting the oral bioavailability of dioxins in rats fed dioxin-contaminated soil. Because of the lack of data reporting the likely bioavailability of dioxin in soil, it was concluded that rat exposures were a reasonable surrogate for cattle.

**10.3.1.1.3 Soil-to-Plant Bioconcentration Factor and Root Concentration Factor.** The soil-to-plant bioconcentration factor (ChemBr) was calculated from the ratio of contaminant concentrations in plant tissues (on a dry weight basis) to those in the soil. This parameter accounts for uptake through the roots into all plant tissues above- and belowground. In contrast, the root concentration factor (RCF) is the ratio of contaminant concentrations in the root tissue of plants (on a fresh weight basis) to those in the soil. The significant difference between these uptake factors is that RCFs are based only on the concentration of constituents in the root tissue. Some contaminants, such as dioxins, are taken up in plant roots and not translocated to aboveground tissues; hence, an RCF uptake factor is more appropriate. The methods for deriving these plant uptake factors are discussed separately here.

#### Soil-to-Plant Bioconcentration Factor

Different approaches were used for metals, organics, and dioxins. For metals, an extensive uptake database was used to generate uptake factors for various plant categories. For organics, uptake factors were calculated based on an empirical relationship between uptake and  $\log K_{ow}$ . Dioxin uptake is addressed in the RCF discussion.

For metals, values for this parameter were adopted from a plant uptake database developed by RTI. The RTI database includes measured uptake factors, which were preferred over calculated empirical regression equations for estimating plant uptake factors for metals (Baes et al., 1984). The database was compiled using field and greenhouse studies of terrestrial plants exposed to metals in which concentrations of metals in stems, roots, leaves, and fruits were measured. The geometric mean of the compiled uptake factors was the final value adopted for this analysis. The plant uptake database was compiled from data identified from the following primary sources:

- # *Risk-Based Concentrations for Arsenic Cadmium, and Lead in Inorganic Commercial Fertilizers* (California Department of Food and Agriculture [CDFA], 1998)
- # Oak Ridge National Laboratory's *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants* (Sample et al., 1997)
- # Oak Ridge National Laboratory's *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants* (U.S. DOE, 1998a)
- # Chaney and Ryan's *Risk Based Standards for Arsenic, Lead, and Cadmium in Urban Soils* (1994).

In developing this database, RTI evaluated plant uptake values used in similar assessments, including the analysis conducted for EPA's *Standards for the Use or Disposal of Sewage Sludge* (40 Code of Federal Register [CFR] Part 503). Uptake factors derived for the Part 503 standards are specific to sewage sludge matrices and as such are less applicable for estimating uptake for this analysis. Uptake data from sewage sludge application were not included in the database because the phytoavailability of metals is significantly lower in sewage sludge-amended soils.



The metal adsorption capacity of sewage sludge (presumed to have different characteristics than industrial sludge, such as more organic carbon) results in increased metal adsorption in sludge-amended soils and, thus, a decreased availability of metals for plant uptake (U.S. DOE, 1998a; Chaney and Ryan, 1994). This is assumed to occur due to the presence of hydrous iron, manganese, and aluminum oxides within the biosolids matrix. Therefore, considerable binding capacity of sewage sludge may result in uptake factors that are biased toward the low end of the range; these factors may not adequately represent typical terrestrial soil matrices.

The plant uptake database includes measured uptake values for commercial agricultural crops as well as for native plant species. The crop data are generally taken from fertilizer-amended soil, while the native species data are more likely exposed to nonamended soil. Furthermore, some of the data are derived from greenhouse or “pot” studies, while some data are from field studies. Comparative studies have shown that plant uptake rates can be significantly higher in greenhouse and pot studies as opposed to field studies (U.S. DOE, 1998a; CDFA, 1998; Chaney and Ryan, 1994). Consideration was given to including each of these types of data in the database. Both amended and nonamended soil data are considered appropriate because both conditions are assumed under HWIR exposure scenarios. Regarding field versus greenhouse data, exclusion of greenhouse data reduces the amount of useful data and, because the level of uncertainty in pot studies has not been quantified for uptake studies, it is more desirable to work with a larger data set within the constraints of the uncertainty. Therefore, both field and greenhouse data have been included. The inclusion of greenhouse data introduces uncertainty and likely alters the true distribution for uptake factors relative to field exposures, because greenhouse data tend to result in more conservative uptake values. The data derived from these literature searches were categorized into the respective plant categories: vegetables (i.e., protected and exposed), fruits (i.e., protected and exposed), forage, grain, root, and silage.

From these data, it was deduced that uptake factors for exposed vegetables, forage, grain, root, and silage could be used from the database. The other plant categories lacked sufficient data across constituents to characterize the variability in uptake factors. In other cases, no data were available to develop chemical-specific uptake factors for metals (e.g., vanadium). In these instances, predicted uptake factors were applied using the regression developed by Baes et al. (1984).

For mercury and methylmercury, values were taken from U.S. EPA (1997a). Data were derived from experiments conducted under reasonable garden conditions, with edible portions of plants grown in control soil and sludge-amended soil. The values were averaged and applied across the various plant types. Insufficient data were identified to develop mercury uptake factors for specific plant categories.

For organics, uptake from soil and transport to aboveground plant parts depend on the solubility of a chemical in water, which is inversely proportional to the octanol-water partition coefficient,  $K_{ow}$ . Travis and Arms (1988, as cited in U.S. EPA, in press) developed an empirical relationship from field experiments on 29 organic chemicals to estimate uptake factors. Values were calculated using Equation 10-3 as follows:

$$\log \text{ChemBr} = 1.588 - 0.578 \log K_{ow} \quad (10-3)$$

For dioxin and furan congeners, uptake into plants through the roots was assessed using root concentration factors (RCFs). The approach is outlined in the following section.

#### Root Concentration Factors (RCFs)

The RCF is an alternative estimator of the soil-to-plant uptake factor, which is used for root crops. The RCF is defined as the ratio of the contaminant concentration in roots (fresh weight) to that in the soil pore water ( $[\mu\text{g contaminant/g plant root FW}]/[\mu\text{g contaminant/mL pore water}]$ ). For metals and mercury translocated across the whole plant, ChemBr uptake values for plants are more appropriate; however, in some cases (e.g., dioxins) most of the constituent remains in plant roots and is not translocated to other tissues. For these constituents, an RCF is a more appropriate uptake factor. For dioxins, the EPA-recommended RCF of 5,200 was used (U.S. EPA, 1997a). These values were calculated using Equation 10-4, as follows:

$$\log(\text{RCF} - 0.82) = 0.77\log K_{ow} - 1.52 \quad (10-4)$$

This relationship also was used to derive RCFs for organic and special constituents with  $\log K_{ow}$  values less than or equal to 2. For constituents with  $\log K_{ow}$  values greater than 2, the empirical relationship in Equation 10-5 was applied (U.S. EPA, 1997a), as follows:

$$\log \text{RCF} = 0.77\log K_{ow} - 1.52 \quad (10-5)$$

**10.3.1.1.4 Mass-Based Air-to-Plant Biotransfer Factor and Empirical Correction Factor.** The parameter ChemBv was used to estimate the plant contaminant concentration due to air-to-plant transfer. This parameter was calculated from the ratio of the contaminant concentrations in aerial plant parts (on a dry weight basis) to the concentrations in the air as vapor. Air-to-plant transfer is likely to be important for exposed produce but not for protected produce or root crops, because only aboveground exposed vegetation encounters deposition from the air. With the exception of mercury, values for metals are set equal to zero because metals do not exist in the vapor phase.

There are few experimental determinations of ChemBv. Simonich and Hites (1994) determined an air-to-plant biotransfer factor of  $4.7\text{E}+4$  for benzo(a)pyrene. All other special chemicals were given a default of 1. Mercury and dioxin values were taken from the geometric mean of measured values presented in U.S. EPA (1997a).

For organic constituents, air-to-plant biotransfer factors were derived according to Equation 10-6 as recommended by U.S. EPA (in press).

$$\log \text{Bvol} = 1.065\log K_{ow} - \log\left[\frac{\text{H}}{\text{RT}}\right] - 1.654 \quad (10-6)$$

The volumetric transfer factor (Bvol) is correlated with the octanol-water partition coefficient ( $K_{ow}$ ), Henry's law constant (H), ideal gas constant (R), and ambient temperature (T). The result of these calculations (Bvol) is transformed into a mass-based biotransfer factor considering leaf density, air density, and percentage of moisture in the leaf. Bv is calculated using Equation 10-7, as follows:

$$Bv = \left( \frac{\rho_{air} \cdot Bvol}{\left( \frac{100 - MAF_{leaf}}{100} \right) \cdot \rho_{leaf}} \right) \cdot \frac{1}{Bv_{ecf_{plant}}} \quad (10-7)$$

where

$\rho_{air}$	=	density of air (constant at 1.19 g/L)
Bvol	=	biotransfer factor ( $[\mu\text{g/L FW leaf}]/[\mu\text{g/L air}]$ )
$MAF_{leaf}$	=	moisture content in leaf (percentage)
$\rho_{leaf}$	=	density of leaf (g/L FW)
$Bv_{ecf_{plant}}$	=	empirical correction factor for Bv (unitless).

For organics, the air-to-plant biotransfer factors calculated using this approach are divided by the empirical correction factor ( $Bv_{ecf_{plant}}$ ) of 100. Predicted values generated using these equations usually result in overly conservative estimates of air-to-plant biotransfer factors. In some cases, the difference can be up to 40 times higher than measured biotransfer factors (McCrary and Maggard, 1993, as cited in U.S. EPA, in press). Other research has indicated that field-derived biotransfer factors were about 2 to 5 times lower than the values generated using equation 10-7 (Lober, 1995, as cited in U.S. EPA, in press). Therefore, the U.S. EPA (in press) recommended correction factor of 100 was applied in this analysis. The rationale for using the correction factor is based on evidence derived from dioxin exposures, but this correction factor also was applied to ChemBv values derived for organic constituents.

**10.3.1.1.5 Plant Surface Loss Coefficients.** This parameter is used to account for environmental processes that could reduce the concentrations of constituents deposited onto plants. The dynamics of deposition change depending on whether the constituent is in a vapor or particulate form. The two variables required are  $kpPar$  for particulate deposition and  $kpVap$  for vapor deposition. The methods applied to derive these parameters are presented separately.

#### Particulate Deposition

The plant surface loss coefficient of particle-bound contaminants,  $kpPar$ , is used by the module to calculate plant concentration due to direct deposition. This coefficient reflects the rate of loss of deposited constituents from the plant surface due to environmental processes (i.e., wind removal, water removal, and growth dilution). The coefficient is directly related to the environmental half-life (Equation 10-8) (Miller and Hoffman, 1983, as cited in U.S. EPA, 1997a):

$$kpPar = \frac{253}{\frac{t_1}{2}} \quad (10-8)$$

In this equation, the  $t_{1/2}$  value (environmental half-life in days) is strongly influenced by local conditions related to wind and precipitation. Because these data were not available on a site-specific and chemical-specific basis, this equation could not be applied. Rather, the EPA-recommended default value of  $18.07 \text{ yr}^{-1}$  was used for all constituents, with the exception of mercury and dioxin (U.S. EPA, 1997a).

For mercury and dioxin, values recommended in U.S. EPA (1997a) were applied. Parameters of  $40.41$  and  $27.06 \text{ yr}^{-1}$  for mercury and dioxin, respectively, were adopted for this analysis. These values were derived as the mean of a data range that were assumed to be lognormally distributed (U.S. EPA, 1997a).

### Vapor Deposition

The plant surface loss coefficient of vapor-phase contaminants,  $kpVap$ , was used as a variable in calculating plant tissue concentrations due to vapor deposition. The degradation of constituents on the plant's surface is due to environmental processes similar to the processes mentioned earlier. For organics, dioxins, and special constituents, this coefficient was derived by taking the midpoint of the range of  $58$  to  $180.7 \text{ yr}^{-1}$  reported in U.S. EPA (in press), which resulted in a  $kpVap$  of  $119.35 \text{ yr}^{-1}$ . For metals and mercury constituents, this vapor-related parameter was not required; hence, in the database, a placeholder value of  $1$  was substituted.

## **10.3.1.2 Database Compilation and Processing for Terrestrial Food Web**

**10.3.1.2.1 Bioaccumulation Factors.** The only parameters exclusive to the terrestrial food web were the chemical-specific bioaccumulation factors (referred to herein as uptake factors) for prey items (ChemBAF). Following a short review of data selection guidelines that were implemented in identifying appropriate uptake factors, the parameters are presented on a prey-specific basis: vertebrates, worms, and invertebrates.

Two general guidelines were used to identify uptake factor studies. These guidelines were not used as strict data standards; rather, they were used to increase the level of confidence and consistency in the values used in the database.

1. Field studies were preferred to laboratory exposures. Because field studies tend to more accurately represent the types of exposures and uptake that occur in natural systems, field-generated uptake factors are regarded with higher confidence than those estimated from laboratory exposure data. For example, uptake factors measured during laboratory exposures may overestimate uptake because biota may be exposed to a more bioavailable form of the constituent. In contrast, processes such as degradation and sorption that occur under field conditions tend to reduce the

uptake of constituents (e.g., by limiting bioavailability). Both field and laboratory exposures were used because available field study data are not adequate to develop all of the uptake factors for this analysis. Pooling both types of values, however, introduces some uncertainty into the database.

2. For use in the HWIR modeling system, the following units for the uptake values were required. In terrestrial ecosystems, uptake factors were in units of kg soil (dry weight)/kg tissue (wet weight) for most prey items. These results were calculated by the ratio of mg constituent/kg body weight (wet weight) to mg constituent/kg soil (dry weight).

### Vertebrate Uptake Factors

Terrestrial vertebrate prey receptors included small mammals, small birds, small herpetofauna, omnivorous vertebrates, and herbivorous vertebrates. Similar approaches were implemented to identify uptake factors for all categories of vertebrates. A few key sources were identified that reported uptake factors for vertebrates. In addition to the primary literature, an additional compendium reference was used that reported uptake factors for metals and 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) in small mammals representing various dietary preferences (i.e., insectivores, herbivores, and omnivores) (Sample, Beauchamp, Efroymsen, and Suter, 1998). Sample, Beauchamp, Efroymsen, and Suter (1998) provided data for a general category of small mammals. The median uptake factor generated for small mammals was applied in this analysis. Sample, Beachamp, Efroymsen, and Suter (1998) developed mammalian uptake factors as screening estimates, and, as such, these values do not reflect national distributions for these parameters. These uptake factors were derived from relatively large databases, however, and the values represent some of the variability in uptake seen across different species and dietary habits.

Significant data gaps remained for categories of vertebrates other than small mammals. The values identified for small mammals were, therefore, used for other categories of vertebrates. The variability associated with rates and physiological regulation of uptake introduces considerable uncertainty in applying small mammal uptake factors to other vertebrate categories. Nevertheless, these values serve as the most reasonable placeholders until exposure-route and species-specific uptake factors become available.

Additional uptake factors for small herpetofauna were identified through primary literature searches. The uptake factors indicating sediment exposures to amphibians that were added to the database are presented in Table 10-6. Because sediments were the only media exposure pathway identified for herpetofauna, these uptake factors were adopted into the database until further soil-based uptake factors are identified. There is uncertainty with applying sediment uptake exposures to represent soil uptake; however, these values act as reasonable placeholders until more representative data are identified.

**Table 10-6. Uptake Factors Identified for Small Amphibians**

Constituent	Species	Lab/Field	Uptake Factors	Source
Arsenic	Tadpole	Field	0.10	Rowe et al., 1996
Cadmium	Tadpole	Field	0.58	Rowe et al., 1996
Chromium	Tadpole	Field	0.04	Rowe et al., 1996
Lead	Tadpole	Field	0.17	Rowe et al., 1996
Selenium	Tadpole	Field	0.83	Rowe et al., 1996

Earthworms

Measured uptake factors for earthworms were identified in both the primary literature and review compendia. Sample, Beauchamp, Efroymsen, Suter, and Ashwood (1998) reported uptake factors for metals in earthworms. Median uptake factors were adopted from this source for the following constituents: arsenic, cadmium, chromium, mercury, nickel, lead, selenium, zinc, barium, beryllium, silver, and vanadium (see Appendix 10A). Worm tissue concentrations in Sample, Beauchamp, Efroymsen, Suter, and Ashwood (1998) were reported on a dry weight basis and, as such, had to be converted to wet weight to be consistent with HWIR model requirements. These values were converted assuming an 84 percent moisture content in earthworms (Sample et al., 1997).

Additional values for 2,3,7,8-TCDD and pentachlorophenol (PCP) identified through primary literature searches are presented in Table 10-7. Final uptake factors for 2,3,7,8-TCDD and PCP were generated by taking the geometric mean of values presented in Table 10-7.

**Table 10-7. Uptake Factors Identified for Earthworms**

Constituent	Species	Lab/Field	Uptake Factors	N	Source
2,3,7,8-TCDD	Not specified	Not specified	15, 9.4, 0.68, 0.64, 0.47	5	U.S. EPA, 1997c
PCP	<i>E. andrei</i>	Lab	0.85, 0.54	2	Van Gestel and Ma, 1988
PCP	<i>L. rubellus</i>	Lab	0.64, 1.28	2	Van Gestel and Ma, 1988
PCP	<i>Lumbricus caliginosa</i>	Both	0.03, 0.02, 0.04, 0.14	4	Haimi et al., 1992

For organics, current methods of estimating uptake into earthworms were identified; however, their use in the TFW module has not been reviewed. The literature reports numerous algorithms to calculate uptake into earthworms; however, the changes in soil composition, water content, and chemical equilibria between different soils makes applying one uptake equation for all soils somewhat unsatisfactory. A widely used method of estimating uptake summarized by Jager (1998) also has been applied in other EPA screening ecological risk assessments (U.S. EPA, 1997b). The method addresses uptake into earthworms as a function of the partitioning between soil and pore water. Concentrations of constituents in pore water are correlated with concentrations in earthworm tissues. Jager (1998) presents the simplified bioconcentration relationship for earthworms (Equation 10-9), as follows:

$$\text{BCF} = \frac{F_{\text{water}} + F_{\text{lipid}} K_{\text{ow}}}{P_{\text{worm}}} \quad (\text{L/kg worm tissue}) \quad (10-9)$$

where

BCF	=	bioconcentration factor (L/kg worm tissue)
$F_{\text{water}}$	=	concentration of constituent in the pore water (mg/L)
$F_{\text{lipid}}$	=	fraction of lipid in earthworm tissue (unitless)
$K_{\text{ow}}$	=	octanol-water partition coefficient for the constituent
$P_{\text{worm}}$	=	bulk density of the worm tissue.

This equation results in uptake factors based on pore water exposures in units of L/kg tissue. The TFW module requires exposures for earthworms to be converted into units of kg soil/kg tissue. Therefore, earthworm uptake factors based on pore water exposures need to be converted into soil exposure estimates using a soil-water partition coefficient ( $K_p$ ). The parameter  $K_p$  uses the relationship between the fraction of organic carbon ( $f_{\text{oc}}$ ) in the soil and the constituent-specific  $K_{\text{oc}}$  to estimate the partitioning of constituents from the soil phase to the pore water phase. Given that site-specific  $f_{\text{oc}}$  data are available, estimation of earthworm uptake would be best represented on a site-specific basis. In addition, an earthworm uptake factor based on site-specific  $f_{\text{oc}}$  would better reflect site-specific conditions, increasing the resolution of exposure to terrestrial receptors. Using an uptake algorithm for earthworms would fill some of the remaining data gaps for this prey item.

### Invertebrates

Uptake factors for invertebrate prey items were the least well-represented in the database. Invertebrate prey species include taxa such as terrestrial and flying arthropods and terrestrial mollusks. The invertebrate prey item category excludes earthworms because they are considered as a separate prey item in the database. The data collection effort evaluated peer-reviewed approaches and data to estimate invertebrate uptake. The most relevant database identified was developed by Oak Ridge National Laboratories (ORNL): a biota-sediment accumulation factor (BSAF) database for aquatic insects (U.S. DOE, 1998b).

The BSAF database contains metal uptake factors primarily for emergent insects that spend a portion of their life in water (usually larval) before metamorphosis into terrestrial insects (e.g., mayflies). The data address uptake of arsenic, cadmium, chromium, mercury, nickel, lead, and zinc. The analysis done by Oak Ridge compared BSAF uptake values measured in aquatic insects to a smaller data set of measured concentrations in terrestrial flying insects. Their findings indicate a correlation between BSAFs in aquatic insects and accumulation in terrestrial insects. The data suggest that BSAFs for benthic aquatic insects can be used to estimate uptake in emergent insects. Some of the comparisons done between aquatic and emergent insect uptake factors indicate that aquatic insect uptake factors tend to underestimate uptake in emergent insects; therefore, the more conservative 90th percentile of the data was recommended for screening-level assessments. The recommended values were adopted as uptake factors for invertebrates in the TFW module. Because these data were presented in terms of dry weight, they were converted to wet weight assuming an 80 percent moisture content for aquatic insects (Sample et al., 1997).

Uptake factors for invertebrates were reported for depurated insects, nondepurated insects, and both combined. The category that combined both types of data were used for this analysis. Typically, uptake factors based on depurated organisms are preferred, but given the lack of data for this category, the variability in this parameter was better represented by combined data.

Uptake factors for selenium in terrestrial insects based on soil concentrations were derived from an additional source (Wu et al., 1995). A summary of the selenium uptake factors identified and incorporated into the database for terrestrial invertebrates is presented in Table 10-8. The geometric mean of the reported data was used in the TFW module (see Appendix 10A for final values).

**10.3.1.3 Assumptions and Uncertainties for Chemical-Specific Database.** This section reviews the key overall uncertainties as well as the parameter-specific uncertainties associated with the chemical-specific database developed in support of the FFC and TFW modules. Discussions are outlined for the specific food webs.

**Table 10-8. Uptake Factors Identified for Invertebrates**

Constituent	Species	Lab/Field	Uptake Factors	N	Source
Selenium	Grasshopper	Field	1.0, 1.0, 1.9, 4.0, 0.11, 11, 0.21	7	Wu et al., 1995
Selenium	Mantis	Field	1.1, 0.78, 4.0, 9.5, 0.23, 29, 0.53	7	Wu et al., 1995



### 10.3.1.3.1 Farm Food Chain Database

#### Variability

The data that were gathered did not consistently represent national distributions of parameters. Instead, the data selected were those recommended by EPA and typically used for diverse risk assessment applications. These data are generally thought to be representative under most regional and climatic conditions. The fact that recommended central tendency values do not always represent regional or national distributions introduces some uncertainty into the data identified.

#### Biotransfer Factors

The recommended default values used for milk and beef biotransfer factors have a great deal of uncertainty (U.S. EPA, 1997a). Default values were derived based primarily on the biotransfer of pesticides data. Evidence suggests that these data may not be appropriate for dioxins or for organics with log  $K_{ow}$  values outside the prescribed range for milk (log  $K_{ow}$  range 2.8 to 6.5) and beef (log  $K_{ow}$  range 1.3 to 6.9). Experimentally derived values are uncertain to the extent that conditions of the study differ greatly from expected conditions in the field. Within the constraints of these uncertainties, these values are the standard for estimating biotransfer relationships in the FFC and are accepted as reasonable estimates for risk assessment applications.

#### Bioavailability Fraction

The bioavailability fraction has some uncertainty associated with use of the default estimate because some chemicals may be much less bioavailable from soil than from plant tissues. Adopting the default of 1 introduces significant conservatism in this parameter.

#### Soil-to-Plant Bioconcentration Factor

Soil-to-plant bioconcentration factors are strongly influenced by the chemical and physical properties of the soil as well as the plant species. Experimental uptake factors for metals derived from the plant uptake database were, in some cases, higher than previously applied uptake factors calculated using correlations developed by Baes et al. (1984). This was probably an artifact of including both field and greenhouse studies. In spite of the added conservatism generated by including greenhouse studies, the plant uptake database was preferred because it contains measured uptake factors that more likely reflect typical exposure scenarios for terrestrial plants.

#### Plant Surface Loss Coefficient

Estimated values for the plant surface loss coefficient for particle-bound contaminants were taken from U.S. EPA (1997a) even though locally measured values are preferable because of the strong influences of local conditions. U.S. EPA (1997a) noted that there was no speciation provided for mercury in the data used to derive this coefficient; therefore, the assumption was

made that the values for each mercury species (total, elemental, and methyl) were equal. In addition, the plant surface loss coefficient for vapor-phase contaminants is uncertain because it is based on limited data.

### **10.3.1.3.2 Terrestrial Food Web Database**

#### Data Gaps and Default Values

The large number of data gaps in the TFW contribute to the uncertainty in estimating exposures to upper-trophic-level consumers in the terrestrial ecosystem. A default uptake factor of 1 was applied when uptake factors were not available. The default value may be high for some constituents that do not significantly bioaccumulate. For example, food chain impacts associated with the transfer of constituents to higher trophic levels are not expected to occur for volatile compounds and semivolatile compounds (e.g., vinyl chloride, methylene chloride, trichloroethylene). Typically, compounds with log  $K_{ow}$  values less than 3.5 do not bioaccumulate to a significant degree. Moreover, many of these compounds volatilize before they are taken up into biota. Further, some of these compounds can be metabolized by enzymatic detoxification mechanisms. In these cases, the default of 1 may overestimate uptake into the tissue. For other compounds, such as benzo(a)pyrene, which have a higher log  $K_{ow}$  value and may bioaccumulate to a more significant degree in prey items, the default value of 1 may underestimate uptake. Data gaps introduce uncertainty into the analysis by limiting the ability to capture the true nature of ingestion exposure for some receptors.

#### Parameter Variability

Uptake factors used in the TFW are not derived from national or regional distributions and, therefore, do not necessarily reflect the variability inherent in these parameters. Rather, the data identified represent median point estimates of uptake for each prey item category. Uptake factors for a particular prey item vary across species, dietary preferences, seasonal resource requirements, and climatic conditions. For instance, Sample, Beauchamp, Efroymsen, and Suter (1998) indicated that vertebrates of varying dietary preferences (i.e., herbivores, omnivores, insectivores) accumulate contaminants to different degrees. There is uncertainty associated with the uptake factors derived for prey items in this analysis because the variability in parameters is not represented in a central tendency value.

#### Vertebrate Uptake Factors

For vertebrate prey items, values identified for small mammals also were applied to other vertebrate prey items. The variability associated with rates and physiological regulation of uptake introduces considerable uncertainty in applying small mammal uptake factors to other vertebrate categories. Nevertheless, these values serve as reasonable placeholders until exposure-route and species-specific uptake factors become available.

### Invertebrate Uptake Factors

For invertebrates, uptake factors based on sediment exposure were adopted in the absence of data quantifying exposure through the soil. This approach introduces uncertainty because these exposure pathways are not equivalent. The primary literature reports uptake factors on various terrestrial insects such as beetles, especially for metals; however, these data are difficult (i.e., costly) to locate through traditional search methods because they are generally found as secondary assessments conducted within larger site-specific risk analyses. The uptake factors adopted from the Oak Ridge work (U.S. DOE, 1998b) represent the best alternative in the midst of current data limitations.

### Amphibian Uptake Factors

As indicated in the discussion of uncertainty for invertebrates uptake factors, amphibian uptake factors identified during primary literature searches were based on sediment exposures rather than the preferred exposure medium of soil (Canton and Sloof, 1982). The fact that amphibians are semiaquatic, spending some of their developmental stages in water, explains the abundance of uptake data associated with sediment exposures. Because only sediment exposure data were identified for herpetofauna, these uptake factors were adopted until further soil-derived uptake factors are identified; however, there is uncertainty with applying sediment exposures to estimate soil uptake values.

The uptake data for amphibians were used to generate uptake factors for the prey category of small herpetofauna. This prey category consists of both reptile and amphibian prey items; however, the uptake factors identified in the primary literature were derived from studies exposing amphibians. Because only amphibians are represented in the uptake data, there is uncertainty that the uptake factors adequately represent the range for reptiles.

Finally, the values identified for small herpetofauna represent only the tadpole life stage. Given the differences that occur during amphibian metamorphosis, uptake rates and tissue burden could change significantly from the tadpole to the adult life stage. The uptake factors identified do not address this source of potential variability.

## **10.3.2 Exposure-Related Parameters**

This section presents the methods used to identify exposure-related data for the FFC and TFW modules. Because the same parameters are used for the FFC and the TFW, discussions are combined.

### **10.3.2.1 Database Compilation and Processing for Farm Food Chain and Terrestrial Food Web**

#### ***10.3.2.1.1 Consumption Rate of Food Items, Soil, and Water by Cattle***

### Plant Consumption Rate

The consumption of grain, forage, and silage ( $Q_p$ ) by beef and dairy cattle, expressed as a daily rate, were adopted from U.S. EPA (1997a). Cattle ingestion rates of seven types of grain, two types of forage, and two types of silage for both beef and dairy cattle were used to derive this parameter. For beef cattle, the average grain, forage, and silage consumption rates are 0.47, 8.8, and 2.5 kg DW/d, respectively. For dairy cattle, the average grain, forage, and silage consumption rates are 2.6, 11, and 3.3 kg DW/d, respectively. These measured values represent average consumption rates for various vegetation types (i.e., grain, forage, and silage) and should be used as defaults in the absence of site-specific values.

### Soil Consumption Rate

The consumption of soil ( $Q_s$ ) by livestock, expressed as a daily rate, was adopted from U.S. EPA (1997a). Soil consumption rates were used to estimate uptake of constituents into animal tissues from inadvertent consumption of soil while feeding. Reported soil ingestion by cattle varies from 1 to 18 percent of dry matter intake (U.S. EPA, 1997a). The EPA-recommended average soil ingestion rates of 0.39 kg DW/d for beef cattle and 0.41 kg DW/d for dairy cattle were adopted for this analysis. These values approximate 3 percent of the total dry matter intake.

### Water Consumption Rates

Water consumption rates ( $Q_w$ ) vary according to many factors, such as breed, body size, air temperature, humidity, and moisture content of feed (Harris and Van Horn, 1992). In general, dairy cattle consume 2 to 4 pounds of water for each pound of feed (dry weight) consumed and an additional 3 to 5 pounds of water per pound of milk produced (Harris and Van Horn, 1992). Rations high in salt or protein increase water intake. Total water intakes consist of direct water ingestion and water intake through feed stocks containing moisture. For instance, feeds such as silage, green chop, or pasture have a high moisture content and contribute to overall water intake, while grains and hays have a low moisture content (University of Nebraska Cooperative Extension, 1998a).

In beef cattle, the average daily water intake of a 1,200-pound cow ranges from 9.5 gal/d (36 L/d) in December and January to 23.0 gal/d (87 L/d) in July (University of Nebraska Cooperative Extension, 1998a). Table 10-9 summarizes water consumption rates of beef cattle across different body weights. For beef cattle, the water intake value of 14.0 gal/d (53 L/d) was used for this analysis. This value was derived as the average water intake on an annual basis of a 1,200-pound beef cow. The water consumption rate was appropriate because it reflected a fully mature beef cow, and it accounted for the annual variation of water intake in this farm food chain receptor.

In dairy cattle, a value of 24.2 gallons of water per day (92 L/d) was derived for this analysis by taking the average of data measured by Harris and Van Horn (1992) (Table 10-10). These data reflect the variability in water consumption of dairy cows across different temperatures and milk production rates. This value falls within the water consumption ranges

**Table 10-9. Daily Water Intake of Beef Cattle (gal/d)**

Month	Average Maximum Temperature	Body Weight of Finishing Cattle			
		600 lb	800 lb	1,000 lb	1,200 lb
January	36 °F	5.5	7.0	8.5	9.5
February	40 °F	6.0	7.5	9.0	10.0
March	50 °F	6.5	8.0	9.5	10.5
April	64 °F	8.0	9.5	11.0	12.5
May	73 °F	9.0	11.0	13.0	14.5
June	78 °F	9.5	12.0	14.0	16.0
July	90 °F	14.5	17.5	20.5	23.0
August	88 °F	14.0	17.0	20.0	22.5
September	78 °F	9.5	12.0	14.0	16.0
October	68 °F	8.5	10.0	12.0	14.0
November	52 °F	6.5	8.0	10.0	10.5
December	38 °F	6.0	7.0	8.5	9.5

Source: University of Nebraska Cooperative Extension, 1998a.

**Table 10-10. Daily Water Intake of Milk-Producing Dairy Cows (gal/d)**

Breed	Volume of Milk Produced	Mean Daytime Temperature, degrees F							Reference
		Not Specified	10-40 °F	50 °F	60 °F	70 °F	80 °F	90 °F	
Jersey	30 lb/d	13 to 15.5	--	--	--	--	--	--	University of Nebraska, 1998b
Guernsey	30 lb/d	13.8 to 16	--	--	--	--	--	--	University of Nebraska, 1998b
Ayrshire, Brown Swiss, Holstein	30 lb/d	14.5 to 17	--	--	--	--	--	--	University of Nebraska, 1998b
Ayrshire, Brown Swiss, Holstein	50 lb/d	24 to 27	--	--	--	--	--	--	University of Nebraska, 1998b
Ayrshire, Brown Swiss, Holstein	80 lb/d	38 to 42	--	--	--	--	--	--	University of Nebraska, 1998b
Ayrshire, Brown Swiss, Holstein	100 lb/d	48 to 52	--	--	--	--	--	--	University of Nebraska, 1998b
1,400 lb cow	40 lb/d	--	15.5	17.2	18.9	20.6	22.4	24.1	Harris & Van Horn, 1992
1,400 lb cow	60 lb/d	--	18.4	20.1	21.9	23.6	25.3	27	Harris & Van Horn, 1992
1,400 lb cow	80 lb/d	--	21.4	23.1	24.8	26.5	28.3	30	Harris & Van Horn, 1992
1,400 lb cow	100 lb/d	--	24.3	26	27.7	29.5	31.2	32.9	Harris & Van Horn, 1992

reported for other cow breeds by the University of Nebraska Cooperative Extension (1998b). In these data, the average daily water intake of Jersey cows producing 30 pounds of milk per day ranged from 13.0 to 15.5 gallons of water per day (49 to 59 L/d). The average daily water intake of Ayrshire, Brown Swiss, and Holstein cows producing up to 100 pounds of milk per day ranged from 48.0 to 52.0 gallons (182 to 202 L/d) of water per day (University of Nebraska Cooperative Extension, 1998b).

**10.3.2.1.2 Fraction of Food Items Grown in Contaminated Soil.** The fraction of each food item (i.e., forage, grain, silage) (F) is used in the FFC module to account for the dietary fraction of contaminated cattle feed. This parameter varies depending on sites, regions, or, moreover, resource availability. A conservative default value of 1 is assumed in the absence of data available to indicate that some portion of the feed used for livestock is not contaminated. No data were located regarding the origin of feed stocks for livestock; hence, a default value of 1 was adopted from U.S. EPA (1997a).

**10.3.2.1.3 Fraction of Wet Deposition that Adheres to Plants.** The fraction of wet deposition ( $F_w$ ) that adheres to a plant as a result of direct deposition was used in the calculation of plant contaminant concentrations. All contaminants that contact plant surfaces due to dry deposition are assumed to remain on the plant surfaces until removed by weathering. Not all contaminant material that intercepts plant surfaces from wet deposition adheres; rather, a portion is assumed to wash off almost immediately. This parameter is a measure of the amount of wet deposition that adheres to the plant surface. The EPA recommends a value of 0.6 for the fraction of wet deposition that adheres to plant surfaces based on data collected during simulated precipitation studies conducted by Hoffman et al. (1992, as cited in U.S. EPA, 1997a).

**10.3.2.1.4 Moisture Adjustment Factor to Convert Dry Weight to Wet Weight.** The moisture adjustment factor (MAF) is used in the FFC module to convert a given quantity of plant material from a fresh weight basis to a dry weight basis or vice versa. The EPA-recommended moisture contents (as percentages) were adopted for the following plant categories: 92 percent for exposed vegetables, 80 percent for protected vegetables, 87 percent for root vegetables, 85 percent for exposed fruits, and 90 percent for protected fruits (U.S. EPA, 1997a).

**10.3.2.1.5 Leaf Density.** The plant density ( $\rho_{\text{leaf}}$ ) of 770 g/L provided in U.S. EPA (in press) was used for this analysis. This plant density value reflects the density reported in grasses. This density more adequately represents the types of vegetation seen in the farm food chain than other available values.

**10.3.2.1.6 Interception Fraction for Plant.** The interception fraction ( $R_p$ ) for plants is the fraction of contaminant particles deposited on the edible portion of plants. Atmospheric deposition is a potential route of exposure for unprotected produce and forage but not for root crops or protected produce (including grains). Plant interception fractions were adopted from U.S. EPA (1997a) for the following plant categories: 0.052 for exposed fruits and vegetables, 0.47 for forage, and 0.44 for silage. Baes et al. (1984) estimated these average interception fractions by taking into account the following variables: recommended field spacing of plants, average plant/fruit sizes, growth, and exposure durations.

**10.3.2.1.7 Length of Plant Exposure to Deposition.** This parameter quantifies the duration of plant exposure ( $t_p$ ) to the deposition of constituents per harvest in years. The parameter only accounts for the edible portion of plants; therefore, this parameter is only applied to exposed produce and forage, not to root crops or protected produce (including grains). Values used in this analysis were taken from U.S. EPA (1997a). Values were derived from data collected by the South Coast Air Quality Management District (SCAQMD) on average growing seasons and from data collected by Belcher and Travis (1989) on the average time between hay harvests (as cited in U.S. EPA, 1997a). The values for different plant categories are as follows: 0.123 yr for exposed vegetables, exposed fruits, and forage and 0.164 yr for silage. Insufficient data were available to estimate exposure duration for other plant categories, and the default  $t_p$  value of 0.164 yr was used.

**10.3.2.1.8 Vapor-Phase Dry Deposition Velocity.** The dry deposition velocity ( $V_{\text{apDvd}}$ ) for vapor-phase contaminants can be derived using Equation 10-10 (U.S. EPA, in press) as follows:

$$\text{VapDvd} = \frac{1}{R_a + R_b + R_c} \quad (10-10)$$

where

- $R_a$  = atmospheric resistance, a function of vertical turbulent transport (s/cm)
- $R_b$  = surface boundary layer resistance, a function of molecular diffusivity (s/cm)
- $R_c$  = plant canopy/leaf resistance, a function of vegetative density, stomatal uptake, surface effects, and humidity (s/cm).

Atmospheric resistance values, however, are difficult to assign and data are limited. Calculated VapDvd values range from 0.01 cm/sec to 1 cm/s (Smith et al., 1995; Trapp and Matthies, 1995; and Sehmel, 1980 as cited in U.S. EPA, in press). The EPA-recommended default value of 1 cm/s was used for this analysis (U.S. EPA, in press). As apparent from the range of values indicated across different studies, this parameter is a conservative estimate of the velocity of dry vapor deposition.

**10.3.2.1.9 Empirical Correction Factor for Plants.** Different correction factors were applied for aboveground and belowground plant uptake values. Each is described separately here.

#### Aboveground Correction Factors

An empirical correction factor ( $VG_{ag}$ ) was used to account for volumetric differences in aboveground plant tissues in exposed fruits and vegetables, forage, and silage. Values to quantify this parameter were taken from U.S. EPA (1997a) for the following plant categories: 0.01 for exposed fruits and vegetables, 1.0 for forage, and 0.5 for silage. The parameter  $VG_{ag}$  is a correction factor used in calculating the contaminant concentration in plant tissue due to air-to-plant transfer for organic chemicals.  $Vg_{ag}$  adjusts for differences in air-to-plant uptake between thin leaves and bulky fruits (U.S. EPA, 1997a). This adjustment, which can be estimated as the surface-area-to-volume ratio, is necessary because lipophilic organic chemicals transferred from the air tend to remain localized in the surface portions of the plant rather than being distributed to the interior portions.

#### Belowground Correction Factors

The empirical correction factor for belowground vegetation ( $Vg_{bg}$ ) is analogous to  $Vg_{ag}$  and adjusts the belowground constituent concentrations for differences in root volume. The recommended default value of 0.01 was used in this analysis (U.S. EPA, 1997a).

**10.3.2.1.10 Crop Yield for Plants.** The yield or standing crop biomass ( $Y_p$ ) values of the edible portion of exposed fruits and vegetables, forage, and silage as recommended by U.S.



EPA (1997a) were used to quantify this parameter. Crop yield was only assessed for vegetation likely to be exposed through direct atmospheric deposition (aboveground plant categories). As summarized in U.S. EPA (1997a), data reflecting average crop productivity for unprotected produce, forage, and silage at the county level were used to quantify this parameter. The following national average crop yields were used for this analysis: 0.18 for exposed vegetables, 0.09 for exposed fruits, 0.31 for forage, and 0.31 for silage (Baes et al., 1984; Shor et al., 1982; and Travis, 1989, as cited in U.S. EPA, 1997a).

**10.3.2.2 Assumptions and Uncertainties for Exposure-Related Parameters.** In this section, the uncertainties associated with the development of the exposure-related database are reviewed. The uncertainty discussion is organized by parameter. Only parameters indicating key uncertainties are discussed.

**10.3.2.2.1 Consumption Rate of Food Items, Soil, and Water by Cattle.** Most of the EPA-recommended values for consumption rates of plants, soil, and water are default values that estimate national averages for these parameters. There are accepted limitations associated with the use of national averages that do not reflect the variability inherent in consumption rates. The consumption rates of food, water, and soil vary with region, physical conditions, climate, breeds, and local agricultural practices. Therefore, there is uncertainty associated with adopting average point estimates for these parameters; however, these values are currently the accepted standard for determining FFC exposures.

**10.3.2.2.2 Fraction of Food Item Grown in Contaminated Soil.** The default value of 1 used for the fraction of food items grown in contaminated soil assumes that the entire cattle diet is equally contaminated. This assumption generates a conservative estimate of exposure because in many cases, some portion of the diet may not contain contaminants. Some uncertainty is introduced by assuming that a receptor's entire diet is derived from contaminated food stocks.

**10.3.2.2.3 Fraction of Wet Deposition that Adheres to Plants.** The primary uncertainty associated with this parameter is the paucity of data available to derive the value. The default parameter was derived using one study. The scarcity of relevant data generates low confidence in the default value generated. In spite of evidence suggesting that water acts to wash contaminants from the surface of the plant, the fraction of constituents that are actually removed has not been well-quantified.

**10.3.2.2.4 Moisture Adjustment Factor to Convert Dry Weight to Wet Weight.** Based on the narrow range of MAF values across various plant groups, limited variability is reflected in this parameter; however, considerable variability within each plant type is apparent. This evidence suggests that site-specific data could possibly vary significantly from default values (U.S. EPA, 1997a). Because the default moisture adjustment was derived as a central tendency value, there is considerable uncertainty that it represents the true variability within plant categories. Lacking site-specific data, the MAF is a reasonable estimate for plant categories, and it is generally accepted for risk assessment applications.

**10.3.2.2.5 Interception Fraction for Plant.** Available data indicate that interception fractions vary across vegetation types. Methods presented in U.S. EPA (1997a) suggest that site-

specific interception fractions are preferred. This analysis is not site-specific, however. Rather, data that reflect national distributions are preferred. No suitable data were identified that represent national distributions for specific plant categories; therefore, default values were applied. Using a single value for all vegetation types introduces some uncertainty into the analysis.

**10.3.2.2.6 Length of Plant Exposure to Deposition.** The default values adopted to estimate the length of vegetation exposure to deposition have considerable uncertainty due to substantial regional variability in the duration of the growing season, insufficient data available to derive default values, and lack of knowledge of the true representativeness of these data (U.S. EPA, 1997a). This parameter is highly dependent on regional conditions, growing practices, and crop types. Because these factors were not accounted for in the derivation of this parameter, there is uncertainty in the values used.

**10.3.2.2.7 Empirical Correction Factors for Plants.** In deriving default values for this parameter, all organic chemicals are assumed to be equally lipophilic, even though organic chemicals differ with regard to their lipophilicity. This simplification contributes to the uncertainty associated with the default values, particularly for the less lipophilic organics that may have limited distribution into the interior plant tissues. This leads to conservative correction factors for less lipophilic constituents (U.S. EPA, 1997a).

**10.3.2.2.8 Crop Yield.** For crop yield, there is considerable uncertainty associated with the use of average values because crop yield varies significantly from one region to another, depending on growing conditions. The average values, however, are based on very extensive databases that capture a large amount of the national variability.

## 10.4 Quality Assurance and Quality Control

The QA/QC functions for data collection of FFC parameters can be thought of in terms of ensuring that data have been interpreted and extracted correctly (technical QA/QC) and verifying that data have been entered correctly (data entry QA/QC). The QA/QC activities implemented for the TFW and FFC module data collection are described in the following sections.

### 10.4.1 Technical QA/QC

Sources used to obtain data for the TFW and FFC modules are generally accepted as authoritative references. Although both U.S. EPA (in press) and U.S. EPA (1997a) are draft documents currently under review, they were the preferred data sources because they were developed in accordance with EPA's policies and standards. Sources consulted to fill the remaining data gaps were reviewed and approved by the technical lead staff member for the data collection task. Once all the data were entered into the database, a second technical staff member manually verified correct data interpretation and accurate data entry. Primary data sources used to derive previous HWIR databases also were reviewed and verified before being included in the database.

### 10.4.2 Data Entry QA/QC

Data entry was performed by hardcopy data entry. A QA/QC check of all values was performed by a second staff member to ensure that the numbers had been correctly entered into the database.

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## Appendix 10A

# Chemical-Specific Database Developed in Support of the Farm Food Chain and Terrestrial Food Web

Chemical Name	Chem CASID	Chem Type	ChemBr_exveg (ug/g DW plant)/ (ug/g soil)	ChemBv_exveg (ug/g DW plant)/ (ug/g air)	ChemBr_proveg (ug/g DW plant)/ (ug/g soil)
Acetonitrile	75-05-8	O	1	1	1
Acrylonitrile	107-13-1	O	1	1	1
Aniline	62-53-3	O	1	1	1
Antimony	7440-36-0	M	2.00E-01	0	2.00E-01
Arsenic	7440-38-2	M	3.20E-03	0	1
Barium	7440-39-3	M	1.50E-01	0	1.50E-01
Benzene	71-43-2	O	1	1	1
Benzo(a)pyrene	50-32-8	S	1	4.70E+04	1
Beryllium	7440-41-7	M	1.00E-02	0	1.00E-02
Bis(2-ethylhexyl) phthalate	117-81-7	S	1	1	1
Cadmium	7440-43-9	M	6.00E-01	0	1
Carbon disulfide	75-15-0	O	1	1	1
Chlorobenzene	108-90-7	O	1	1	1
Chloroform	67-66-3	O	1	1	1
Chromium (total)	7440-47-3	M	5.70E-04	0	1
Chromium III (insoluble salts)	16065-83-1	M	5.70E-04	0	1
Chromium VI	18540-29-9	M	5.70E-04	0	1
Dibenz(a,h)anthracene	53-70-3	S	1	1	1
Dichlorophenoxyacetic acid, 2,4-(2,4-D)	94-75-7	O	1	1	1
Ethylene dibromide	106-93-4	O	1	1	1
Hexachloro-1,3-butadiene	87-68-3	O	1	1	1
Lead	7439-92-1	M	3.80E-02	0	1
Mercury	7439-97-6	Hg	1.00E-01	1.97E+04	1.40E-02
Mercury (elemental)	7439-97-6e	Hg	1.00E-01	1.97E+04	1.40E-02
Methylmercury	7439-97-6m	Hg	2.30E-02	3.30E+03	3.30E-02
Methoxychlor	72-43-5	O	1	1	1
Methyl ethyl ketone	78-93-3	O	1	1	1
Methyl methacrylate	80-62-6	O	1	1	1
Methylene chloride	75-09-2	O	1	1	1
Nickel	7440-02-0	M	5.10E-02	0	6.00E-02
Nitrobenzene	98-95-3	O	1	1	1
Pentachlorophenol	87-86-5	O	1	1	1
Phenol	108-95-2	O	1	1	1
Pyridine	110-86-1	O	1	1	1
Selenium	7783-79-1	M	2.50E-02	0	2.50E-02
Silver	7440-22-4	M	4.00E-01	0	1
TCDD, 2,3,7,8-	1746-01-6	D	0	6.55E+04	1
Tetrachloroethylene	127-18-4	O	1	1	1
Thallium	7446-18-6	M	4.00E-03	0	4.00E-03
Thiram	137-26-8	O	1	1	1
Toluene	108-88-3	O	1	1	1
Trichloroethane, 1,1,1-	71-55-6	O	1	1	1
Trichloroethylene	79-01-6	O	1	1	1
Vanadium	7440-62-2	M	5.50E-03	0	5.50E-03
Vinyl chloride	75-01-4	O	1	1	1
Zinc	7440-66-6	M	3.70E-01	0	1

## Appendix 10A. (continued)

Chemical Name	ChemBr_exfruit (ug/g DW plant)/ (ug/g soil)	ChemBv_exfruit (ug/g DW plant)/ (ug/g air)	ChemBr_profruit (ug/g DW plant)/ (ug/g soil)	ChemBr_root (ug/g DW plant)/ (ug/g soil)
Acetonitrile	1	1	1	1
Acrylonitrile	1	1	1	1
Aniline	1	1	1	1
Antimony	2.00E-01	0	2.00E-01	3.00E-02
Arsenic	4.00E-02	0	1	6.70E-02
Barium	1.50E-01	0	1.50E-01	1.50E-02
Benzene	1	1	1	1
Benzo(a)pyrene	1	4.70E+04	1	1
Beryllium	1.00E-02	0	1.00E-02	1.50E-03
Bis(2-ethylhexyl) phthalate	1	1	1	1
Cadmium	5.50E-01	0	1	4.00E-01
Carbon disulfide	1	1	1	1
Chlorobenzene	1	1	1	1
Chloroform	1	1	1	1
Chromium (total)	7.50E-03	0	1	6.60E-04
Chromium III (insoluble salts)	7.50E-03	0	1	6.60E-04
Chromium VI	7.50E-03	0	1	6.60E-04
Dibenz(a,h)anthracene	1	1	1	1
Dichlorophenoxyacetic acid, 2,4-(2,4-D)	1	1	1	1
Ethylene dibromide	1	1	1	1
Hexachloro-1,3-butadiene	1	1	1	1
Lead	1.50E-01	0	1	3.00E-02
Mercury	1.80E-02	1.97E+04	1.40E-02	3.50E-02
Mercury (elemental)	1.80E-02	1.97E+04	1.40E-02	3.50E-02
Methylmercury	2.30E-02	3.30E+03	3.30E-02	9.90E-02
Methoxychlor	1	1	1	1
Methyl ethyl ketone	1	1	1	1
Methyl methacrylate	1	1	1	1
Methylene chloride	1	1	1	1
Nickel	6.00E-02	0	6.00E-02	2.70E-02
Nitrobenzene	1	1	1	1
Pentachlorophenol	1	1	1	1
Phenol	1	1	1	1
Pyridine	1	1	1	1
Selenium	2.50E-02	0	2.50E-02	2.50E-02
Silver	4.00E-01	0	1	1.00E-01
TCDD, 2,3,7,8-	0	6.55E+04	1	1
Tetrachloroethylene	1	1	1	1
Thallium	4.00E-03	0	4.00E-03	4.00E-04
Thiram	1	1	1	1
Toluene	1	1	1	1
Trichloroethane, 1,1,1-	1	1	1	1
Trichloroethylene	1	1	1	1
Vanadium	5.50E-03	0	5.50E-03	3.00E-03
Vinyl chloride	1	1	1	1
Zinc	1.50E+00	0	1	2.30E-01

## Appendix 10A. (continued)

Chemical Name	ChemRCF (ug/g WWplant)/ (ug/mL soil water)	ChemBr_grain (ug/g DW plant)/ (ug/g soil)	ChemBr_silage (ug/g DW plant)/ (ug/g soil)	ChemBv_silage (ug/g DW plant)/ (ug/g air)
Acetonitrile	1	1	1	1
Acrylonitrile	1	1	1	1
Aniline	1	1	1	1
Antimony	1	2.00E-01	2.00E-01	0
Arsenic	1	4.00E-02	1.80E-02	0
Barium	1	1.50E-01	1.50E-01	0
Benzene	1	1	1	1
Benzo(a)pyrene	1	1	1	4.70E+04
Beryllium	1	1.00E-02	1.00E-02	0
Bis(2-ethylhexyl) phthalate	1	1	1	1
Cadmium	1	5.50E-02	2.10E-01	0
Carbon disulfide	1	1	1	1
Chlorobenzene	1	1	1	1
Chloroform	1	1	1	1
Chromium (total)	1	8.50E-05	9.30E-03	0
Chromium III (insoluble salts)	1	8.50E-05	9.30E-03	0
Chromium VI	1	8.50E-05	9.30E-03	0
Dibenz(a,h)anthracene	1	1	1	1
Dichlorophenoxyacetic acid, 2,4-(2,4-D)	1	1	1	1
Ethylene dibromide	1	1	1	1
Hexachloro-1,3-butadiene	1	1	1	1
Lead	1	7.40E-03	6.70E-02	0
Mercury	1	8.90E-02	7.80E-01	1.80E+04
Mercury (elemental)	1	8.90E-02	7.80E-01	1.80E+04
Methylmercury	1	1.90E-02	7.80E-01	5.00E+03
Methoxychlor	1	1	1	1
Methyl ethyl ketone	1	1	1	1
Methyl methacrylate	1	1	1	1
Methylene chloride	1	1	1	1
Nickel	1	7.00E-02	1.70E-01	0
Nitrobenzene	1	1	1	1
Pentachlorophenol	1	1	1	1
Phenol	1	1	1	1
Pyridine	1	1	1	1
Selenium	1	2.50E-02	2.50E-02	0
Silver	1	4.00E-01	4.00E-01	0
TCDD, 2,3,7,8-	5200	0	0	6.55E+04
Tetrachloroethylene	1	1	1	1
Thallium	1	4.00E-03	4.00E-03	0
Thiram	1	1	1	1
Toluene	1	1	1	1
Trichloroethane, 1,1,1-	1	1	1	1
Trichloroethylene	1	1	1	1
Vanadium	1	5.50E-03	5.50E-03	0
Vinyl chloride	1	1	1	1
Zinc	1	1.80E-01	1.60E+00	0



## Appendix 10A. (continued)

Chemical Name	ChemBr_forage (ug/g DW plant)/ (ug/g soil)	ChemBv_forage (ug/g DW plant)/ (ug/g air)	Chem Ba_milkd/g	Chem Ba_beefd/g	Chem Ba_waterd/g
Acetonitrile	1	1	1.00E+00	1.00E+00	1
Acrylonitrile	1	1	1.00E+00	1.00E+00	1
Aniline	1	1	1.00E+00	1.00E+00	1
Antimony	2.00E-01	0	1.00E-07	1.00E-06	1
Arsenic	7.10E-02	0	6.00E-08	2.00E-06	1
Barium	1.50E-01	0	3.50E-07	1.50E-07	1
Benzene	1	1	1.00E+00	1.00E+00	1
Benzo(a)pyrene	1	4.70E+04	1.00E+00	1.00E+00	1
Beryllium	1.00E-02	0	9.00E-10	1.00E-06	1
Bis(2-ethylhexyl) phthalate	1	1	1.00E+00	1.00E+00	1
Cadmium	3.10E-01	0	1.00E-06	5.50E-07	1
Carbon disulfide	1	1	1.00E+00	1.00E+00	1
Chlorobenzene	1	1	1.00E+00	1.00E+00	1
Chloroform	1	1	1.00E+00	1.00E+00	1
Chromium (total)	1.90E-03	0	1.50E-06	5.50E-06	1
Chromium III (insoluble salts)	1.90E-03	0	1.50E-06	5.50E-06	1
Chromium VI	1.90E-03	0	1.50E-06	5.50E-06	1
Dibenz(a,h)anthracene	1	1	1.00E+00	1.00E+00	1
Dichlorophenoxyacetic acid, 2,4-(2,4-D)	1	1	1.00E+00	1.00E+00	1
Ethylene dibromide	1	1	1.00E+00	1.00E+00	1
Hexachloro-1,3-butadiene	1	1	1.00E+00	1.00E+00	1
Lead	8.30E-02	0	2.50E-07	3.00E-07	1
Mercury	2.50E-01	1.80E+04	2.60E-06	7.70E-06	1
Mercury (elemental)	2.50E-01	1.80E+04	2.60E-06	7.70E-06	1
Methylmercury	2.50E-01	5.00E+03	2.60E-06	7.70E-06	1
Methoxychlor	1	1	1.00E+00	1.00E+00	1
Methyl ethyl ketone	1	1	1.00E+00	1.00E+00	1
Methyl methacrylate	1	1	1.00E+00	1.00E+00	1
Methylene chloride	1	1	1.00E+00	1.00E+00	1
Nickel	4.30E-02	0	1.00E-06	6.00E-06	1
Nitrobenzene	1	1	1.00E+00	1.00E+00	1
Pentachlorophenol	1	1	1.00E+00	1.00E+00	1
Phenol	1	1	1.00E+00	1.00E+00	1
Pyridine	1	1	1.00E+00	1.00E+00	1
Selenium	2.50E-02	0	4.00E-06	1.50E-05	1
Silver	4.00E-01	0	2.00E-05	3.00E-06	1
TCDD, 2,3,7,8-	0	6.55E+04	1.00E-05	5.40E-05	1
Tetrachloroethylene	1	1	1.00E+00	1.00E+00	1
Thallium	4.00E-03	0	2.00E-06	4.00E-05	1
Thiram	1	1	1.00E+00	1.00E+00	1
Toluene	1	1	1.00E+00	1.00E+00	1
Trichloroethane, 1,1,1-	1	1	1.00E+00	1.00E+00	1
Trichloroethylene	1	1	1.00E+00	1.00E+00	1
Vanadium	4.80E-03	0	2.00E-08	2.50E-06	1
Vinyl chloride	1	1	1.00E+00	1.00E+00	1
Zinc	2.90E-01	0	1.00E-05	1.00E-04	1

## Appendix 10A. (continued)

Chemical Name	ChemBs fraction	Chem BAFbirds_sm unitless	Chem BAFherbiverts unitless	Chem BAFherp_sm unitless	Chem BAFinvert unitless
Acetonitrile	1	1	1	1	1
Acrylonitrile	1	1	1	1	1
Aniline	1	1	1	1	1
Antimony	1	1	1	1	1
Arsenic	1	0.0025	0.0025	0.1	0.14
Barium	1	0.057	0.057	0.057	1
Benzene	1	1	1	1	1
Benzo(a)pyrene	1	1	1	1	1
Beryllium	1	1	1	1	1
Bis(2-ethylhexyl) phthalate	1	1	1	1	1
Cadmium	1	0.33	0.33	0.58	1.6
Carbon disulfide	1	1	1	1	1
Chlorobenzene	1	1	1	1	1
Chloroform	1	1	1	1	1
Chromium (total)	1	0.085	0.085	0.04	0.09
Chromium III (insoluble salts)	1	0.085	0.085	0.04	0.09
Chromium VI	1	0.085	0.085	0.04	0.09
Dibenz(a,h)anthracene	1	1	1	1	1
Dichlorophenoxyacetic acid, 2,4-(2,4-D)	1	1	1	1	1
Ethylene dibromide	1	1	1	1	1
Hexachloro-1,3-butadiene	1	1	1	1	1
Lead	1	2.70E-01	2.70E-01	1.70E-01	1.20E-01
Mercury	1	2.1	2.1	2.1	0.57
Mercury (elemental)	1	2.1	2.1	2.1	0.57
Methylmercury	1	2.1	2.1	2.1	0.57
Methoxychlor	1	1	1	1	1
Methyl ethyl ketone	1	1	1	1	1
Methyl methacrylate	1	1	1	1	1
Methylene chloride	1	1	1	1	1
Nickel	1	0.25	0.25	0.25	0.63
Nitrobenzene	1	1	1	1	1
Pentachlorophenol	1	0.17	0.17	0.17	1
Phenol	1	1	1	1	1
Pyridine	1	1	1	1	1
Selenium	1	0.16	0.16	0.83	1.5
Silver	1	0.004	0.004	0.004	1
TCDD, 2,3,7,8-	0.65	1.1	1.1	1.1	1
Tetrachloroethylene	1	1	1	1	1
Thallium	1	0.11	0.11	0.11	1
Thiram	1	1	1	1	1
Toluene	1	1	1	1	1
Trichloroethane, 1,1,1-	1	1	1	1	1
Trichloroethylene	1	1	1	1	1
Vanadium	1	0.012	0.012	0.012	1
Vinyl chloride	1	1	1	1	1
Zinc	1	0.77	0.77	0.77	1.5

## Appendix 10A. (continued)

Chemical Name	ChemBAF mammals_sm unitless	ChemBAF omniverts unitless	ChemBAF worms unitless	Chemkp Par_exveg 1/y	Chemkp Par_exfruit 1/y
Acetonitrile	1	1	1	18.07	18.07
Acrylonitrile	1	1	1	18.07	18.07
Aniline	1	1	1	18.07	18.07
Antimony	1	1	1	18.07	18.07
Arsenic	0.0025	0.0025	0.035	18.07	18.07
Barium	0.057	0.057	0.015	18.07	18.07
Benzene	1	1	1	18.07	18.07
Benzo(a)pyrene	1	1	1	18.07	18.07
Beryllium	1	1	0.007	18.07	18.07
Bis(2-ethylhexyl) phthalate	1	1	1	18.07	18.07
Cadmium	0.33	0.33	1.2	18.07	18.07
Carbon disulfide	1	1	1	18.07	18.07
Chlorobenzene	1	1	1	18.07	18.07
Chloroform	1	1	1	18.07	18.07
Chromium (total)	0.085	0.085	0.049	18.07	18.07
Chromium III (insoluble salts)	0.085	0.085	0.049	18.07	18.07
Chromium VI	0.085	0.085	0.049	18.07	18.07
Dibenz(a,h)anthracene	1	1	1	18.07	18.07
Dichlorophenoxyacetic acid, 2,4-(2,4-D)	1	1	1	18.07	18.07
Ethylene dibromide	1	1	1	18.07	18.07
Hexachloro-1,3-butadiene	1	1	1	18.07	18.07
Lead	0.105	2.70E-01	0.043	18.07	18.07
Mercury	0.054	2	0.27	40.41	40.41
Mercury (elemental)	0.054	2	0.27	40.41	40.41
Methylmercury	0.054	2	0.27	40.41	40.41
Methoxychlor	1	1	1	18.07	18.07
Methyl ethyl ketone	1	1	1	18.07	18.07
Methyl methacrylate	1	1	1	18.07	18.07
Methylene chloride	1	1	1	18.07	18.07
Nickel	0.25	0.25	0.17	18.07	18.07
Nitrobenzene	1	1	1	18.07	18.07
Pentachlorophenol	0.17	0.17	1.80E-01	18.07	18.07
Phenol	1	1	1	18.07	18.07
Pyridine	1	1	1	18.07	18.07
Selenium	0.16	0.16	0.16	18.07	18.07
Silver	0.004	0.004	0.33	18.07	18.07
TCDD, 2,3,7,8-	1.1	1.1	1.9	27.06	27.06
Tetrachloroethylene	1	1	1	18.07	18.07
Thallium	0.11	0.11	1	18.07	18.07
Thiram	1	1	1	18.07	18.07
Toluene	1	1	1	18.07	18.07
Trichloroethane, 1,1,1-	1	1	1	18.07	18.07
Trichloroethylene	1	1	1	18.07	18.07
Vanadium	0.012	0.012	0.007	18.07	18.07
Vinyl chloride	1	1	1	18.07	18.07
Zinc	0.77	0.77	0.51	18.07	18.07

## Appendix 10A. (continued)

Chemical Name	ChemkpPar_silage 1/y	ChemkpPar_forage 1/y	ChemBv_ecf_plant unitless	ChemkpVap_exveg 1/y
Acetonitrile	18.07	18.07	100	119.35
Acrylonitrile	18.07	18.07	100	119.35
Aniline	18.07	18.07	100	119.35
Antimony	18.07	18.07	1	1
Arsenic	18.07	18.07	1	1
Barium	18.07	18.07	1	1
Benzene	18.07	18.07	100	119.35
Benzo(a)pyrene	18.07	18.07	100	119.35
Beryllium	18.07	18.07	1	1
Bis(2-ethylhexyl) phthalate	18.07	18.07	100	119.35
Cadmium	18.07	18.07	1	1
Carbon disulfide	18.07	18.07	100	119.35
Chlorobenzene	18.07	18.07	100	119.35
Chloroform	18.07	18.07	100	119.35
Chromium (total)	18.07	18.07	1	1
Chromium III (insoluble salts)	18.07	18.07	1	1
Chromium VI	18.07	18.07	1	1
Dibenz(a,h)anthracene	18.07	18.07	100	119.35
Dichlorophenoxyacetic acid, 2,4-(2,4-D)	18.07	18.07	100	119.35
Ethylene dibromide	18.07	18.07	100	119.35
Hexachloro-1,3-butadiene	18.07	18.07	100	119.35
Lead	18.07	18.07	1	1
Mercury	40.41	40.41	1	1
Mercury (elemental)	40.41	40.41	1	1
Methylmercury	40.41	40.41	1	1
Methoxychlor	18.07	18.07	100	119.35
Methyl ethyl ketone	18.07	18.07	100	119.35
Methyl methacrylate	18.07	18.07	100	119.35
Methylene chloride	18.07	18.07	100	119.35
Nickel	18.07	18.07	1	1
Nitrobenzene	18.07	18.07	100	119.35
Pentachlorophenol	18.07	18.07	100	119.35
Phenol	18.07	18.07	100	119.35
Pyridine	18.07	18.07	100	119.35
Selenium	18.07	18.07	1	1
Silver	18.07	18.07	1	1
TCDD, 2,3,7,8-	27.06	27.06	1	119.35
Tetrachloroethylene	18.07	18.07	100	119.35
Thallium	18.07	18.07	1	1
Thiram	18.07	18.07	100	119.35
Toluene	18.07	18.07	100	119.35
Trichloroethane, 1,1,1-	18.07	18.07	100	119.35
Trichloroethylene	18.07	18.07	100	119.35
Vanadium	18.07	18.07	1	1
Vinyl chloride	18.07	18.07	100	119.35
Zinc	18.07	18.07	1	1

## Appendix 10A. (continued)

Chemical Name	ChemkpVap_exfruit1/y	ChemkpVap_silage1/y	ChemkpVap_forage1/y
Acetonitrile	119.35	119.35	119.35
Acrylonitrile	119.35	119.35	119.35
Aniline	119.35	119.35	119.35
Antimony	1	1	1
Arsenic	1	1	1
Barium	1	1	1
Benzene	119.35	119.35	119.35
Benzo(a)pyrene	119.35	119.35	119.35
Beryllium	1	1	1
Bis(2-ethylhexyl) phthalate	119.35	119.35	119.35
Cadmium	1	1	1
Carbon disulfide	119.35	119.35	119.35
Chlorobenzene	119.35	119.35	119.35
Chloroform	119.35	119.35	119.35
Chromium (total)	1	1	1
Chromium III (insoluble salts)	1	1	1
Chromium VI	1	1	1
Dibenz(a,h)anthracene	119.35	119.35	119.35
Dichlorophenoxyacetic acid, 2,4- (2,4-D)	119.35	119.35	119.35
Ethylene dibromide	119.35	119.35	119.35
Hexachloro-1,3-butadiene	119.35	119.35	119.35
Lead	1	1	1
Mercury	1	1	1
Mercury (elemental)	1	1	1
Methylmercury	1	1	1
Methoxychlor	119.35	119.35	119.35
Methyl ethyl ketone	119.35	119.35	119.35
Methyl methacrylate	119.35	119.35	119.35
Methylene chloride	119.35	119.35	119.35
Nickel	1	1	1
Nitrobenzene	119.35	119.35	119.35
Pentachlorophenol	119.35	119.35	119.35
Phenol	119.35	119.35	119.35
Pyridine	119.35	119.35	119.35
Selenium	1	1	1
Silver	1	1	1
TCDD, 2,3,7,8-	119.35	119.35	119.35
Tetrachloroethylene	119.35	119.35	119.35
Thallium	1	1	1
Thiram	119.35	119.35	119.35
Toluene	119.35	119.35	119.35
Trichloroethane, 1,1,1-	119.35	119.35	119.35
Trichloroethylene	119.35	119.35	119.35
Vanadium	1	1	1
Vinyl chloride	119.35	119.35	119.35
Zinc	1	1	1

## Appendix 10B

### Exposure-Related Database Developed in Support of the Farm Food Chain and Terrestrial Food Web

Data_Group_Name	Variable_Name	Units	Central_Tendency
terrestrial foodweb	Bv_ecf_plant	unitless	100
terrestrial foodweb	Rp_forage	unitless	0.47
terrestrial foodweb	MAFroot	percent	87
terrestrial foodweb	VGag_exfruit	unitless	0.01
terrestrial foodweb	VapDdv	cm/sec	1
terrestrial foodweb	tp_silage	y	0.16
terrestrial foodweb	tp_forage	y	0.12
terrestrial foodweb	tp_exveg	y	0.123
terrestrial foodweb	tp_exfruit	y	0.123
terrestrial foodweb	Rp_silage	unitless	0.44
terrestrial foodweb	Fw_silage	unitless	0.6
terrestrial foodweb	Fw_forage	unitless	0.6
terrestrial foodweb	Yp_silage	kg DW/m <sup>2</sup>	0.31
terrestrial foodweb	Yp_forage	kg DW/m <sup>2</sup>	0.31
terrestrial foodweb	Yp_exveg	kg DW/m <sup>2</sup>	0.18
terrestrial foodweb	Yp_exfruit	kg DW/m <sup>2</sup>	0.09
terrestrial foodweb	VGbg_root	unitless	0.01
terrestrial foodweb	VGag_silage	unitless	0.5

(continued)

## Appendix 10B. (continued)

Data_Group_Name	Variable_Name	Units	Central_Tendency
terrestrial foodweb	VGag_forage	unitless	1
terrestrial foodweb	Fw_exveg	unitless	0.6
terrestrial foodweb	Fw_exfruit	unitless	0.6
terrestrial foodweb	Rp_exveg	unitless	0.05
terrestrial foodweb	MAFexveg	percent	92
terrestrial foodweb	MAFforage	percent	92
terrestrial foodweb	MAFgrain	percent	90
terrestrial foodweb	MAFleaf	unitless	85
terrestrial foodweb	MAFexfruit	percent	85
terrestrial foodweb	VGag_exveg	unitless	0.01
terrestrial foodweb	rho_leaf	g/L FW	770
terrestrial foodweb	Rp_exfruit	unitless	0.052
terrestrial foodweb	MAFsilage	percent	92